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### Covid19, Mucociliary Clearance And Mechanisms of Beneficial Effects of Various Yoga Practices

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#### ABSTRACT: -

The Coronavirus Disease 2019 (COVID19) outbreak is one of the biggest pandemics reported in the history. Widespread prevalence of COVID19 have not only caused the respiratory consequences, but also psychological effects because of its fear. Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) is the virus responsible for COVID19 and have been reported to cause impairment in mucociliary clearance (MCC) as a result of damage to the ciliary layer of respiratory epithelium. Because MCC is one of the important defense process of respiratory system, impairment of MCC could be one of the important mechanisms of progression of COVID19. Yoga is a multidimensional system of practices for physical, mental, and spiritual health popularly practiced all over the world for physical and mental well-being. This article summarizes various components of COVID19, effect on mucociliary clearance, role of nitric oxide and various mechanisms of beneficial effects of yoga asana, pranayama, mantra chanting and meditation for prevention and treatment of COVID19.

**Keywords:-** COVID19, Mucociliary clearance, Nitric oxide, Yoga practices, Humming sound



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## INTRODUCTION

Illness can be defined as a condition of disease(s) affecting the body and / or mind of the affected person. Disease is an abnormal condition that adversely affects the structure or function of all or part of an organism. Illness in human body has not just a physical or mechanical component, it also has mental / psychological or emotional component. This feature of illness of human distinguish human from machine. The mind and body of an affected person interact with each other, and as a result of this mind body interaction, the psychological / mental state and physical condition of the person deteriorate<sup>[1]</sup>. Both of these components of illness contribute to each other and contribute to the illness progression, if body and mind are not able to handle the illness or the illness is not treated externally. COVID19 is a pandemic caused by SARS-CoV-2<sup>[2]</sup> and the disease condition progresses because of the SARS-CoV-2 as well as because of the fear and stress, caused by the knowledge of patient about the data of COVID19 related serious conditions or deaths<sup>[3,4]</sup>.

Yoga is a scientific practices for maintaining physical, mental and spiritual health. It is practiced all over the world for physical and mental well-being. Although yoga originally is not therapy, practice of it produces beneficial effects and hence is also used as therapy and now, yoga practices are related to health, peace and happiness. Many countries supported the yoga as one of the important practices of complementary and alternative medicine. The

United Nations General Assembly has declared 21st June as the International Day of Yoga. As of today, there are more than 300 million yoga practitioners worldwide and the number is increasing every day. In addition to that, yoga is practiced for prevention as well as treatment of many diseases and yoga therapy has become one of the emerging therapeutic choice for patients across the globe.

## METHODOLOGY

Thorough literature search was carried out on internet in various free databases, published scientific journal articles and books for review of various components of COVID19, its impact on respiratory system, role of nitric oxide and mucociliary clearance, effect of yoga practices on human body and mind. The scientific ideas discussed in the literature were linked with each other and the content of the current review article was designed from it.

## DISCUSSION

If we look the COVID19, it has 2 main components causing all the consequences.

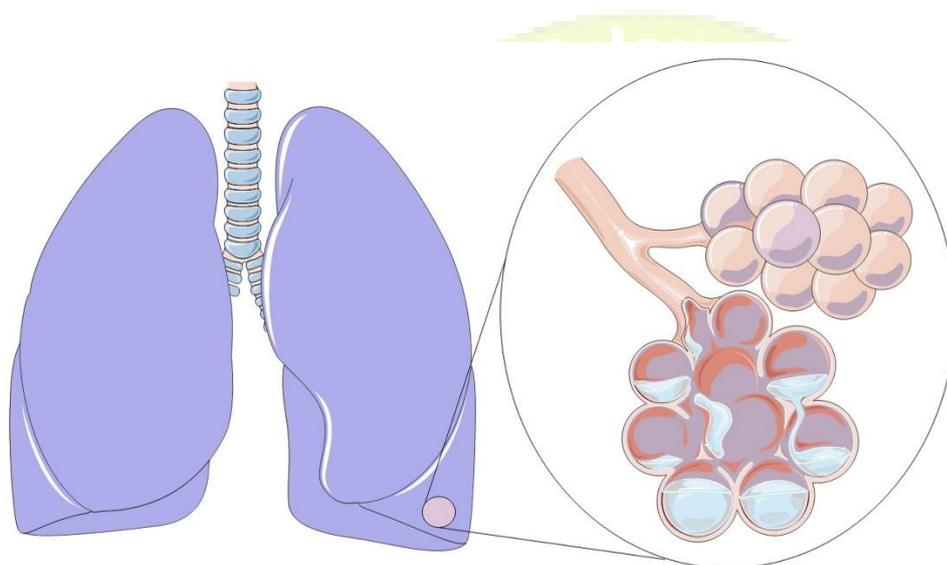
- 1) Mechanical component
- 2) Emotional / Psychological Component

### Mechanical Component of COVID19

The initial cases of COVID19 were associated with direct exposure to the Seafood Market of Wuhan, the transmission from animal to human has been presumed, which subsequently has been spread from the one infected person to other through respiratory droplets from

coughing and sneezing<sup>[2]</sup>. The SARS-CoV-2 enter the human body through nose or mouth and interact with tissues of nose, throat, lungs and gastrointestinal tract (GIT). In most of the cases, body is able to handle the virus at this stage and can eliminate from the body via mucous secretion, or by effect of gastric acid in stomach. But if, the body is not able to trap and eliminate the virus at this stage, the virus may enter into the cell at these affected locations, especially in respiratory tract and uses the

machinery of the human cell to produce more viruses. The localized viral load at these location increases and also, the affected body continue to produce immune response to counter the increased viral load. The body keep on producing mucous which get accumulated in alveoli and interfere with the respiration (Fig 1). The virus may enter the systemic circulation from here and continue to spread in the body through systemic circulation



**Fig 1. Mucus in alveoli interfering gaseous exchange**

The body produces anti-bodies to remove the virus. But if, because of many limitations of the body (e.g. compromised immune function because of diseases or stress), the body will not be able to handle the virus and overall viral load goes on increasing. Because of increasing viral load, body produces systemic inflammatory reactions characterized by cytokine storm and complement system activation which damages the tissues having high viral load<sup>[2]</sup>. The alveolar membrane become thick and inflamed which further contribute to difficulties in breathing. In this condition, sudden progressive severe / acute respiratory distress syndrome

(SRDS / ARDS) develops; and patient need supportive ventilation. If the condition does not improve at this stage, the patient may enter into severe hypoxia and results in death<sup>[2]</sup>.

### **Emotional / Psychological Component of COVID19**

COVID19 is pandemic and associated with mortalities. Although mortality rate is less if compared with other epidemics, the number of deaths are high because of widespread infection all over the world. COVID19 pandemic has caused heavy psychological impact among healthy population and also amongst patients with any pre-existing conditions or

COVID19<sup>[3]</sup>. The most common indicators of psychological impact reported across studies were anxiety and depression<sup>[3]</sup>. Research on the psychological reactions to epidemics and pandemics suggests that various psychological vulnerability factors play a role in coronaphobia, including individual factors such as the intolerance of uncertainty, perceived vulnerability to disease, and anxiety (worry) proneness<sup>[4]</sup>. All these increases stress, affects the sleep pattern and eventually affect the cortisol cycle, a hypothalamic pituitary adrenal (HPA) axis function<sup>[5]</sup>. Effect on cortisol cycle compromises the immunity and increases risk of progressing towards to serious condition or death in COVID19<sup>[6]</sup>. Thus, the emotional component greatly contribute to the serious risk in COVID19.

### Stage of COVID19

Based on the cells that are likely infected in COVID19, the disease can be divided into three phases that correspond to different clinical stages of the disease<sup>[7]</sup>.

Stage 1: Asymptomatic state of initial 1-2 days of infection

At this stage, there is local propagation of the virus but a limited innate immune response present. The virus can be detected by nasal swabs, although the viral burden may be low. The person is usually asymptomatic at this stage<sup>[7]</sup>.

Stage 2: Upper airway and conducting airway response

The virus transmits deep in the respiratory tract along the conducting airways and a more robust innate immune response is triggered at this stage of the disease. The virus is detectable in the nasal swabs or sputum samples. Also early markers of the innate immune response are

detectable at this stage and the disease manifests clinically with its symptoms. But, the disease remains mild to moderate. The upper respiratory track including bronchi and bronchioles are involved at this stage for about 80% of the cases<sup>[7]</sup>.

Stage 3: Hypoxia and ARDS

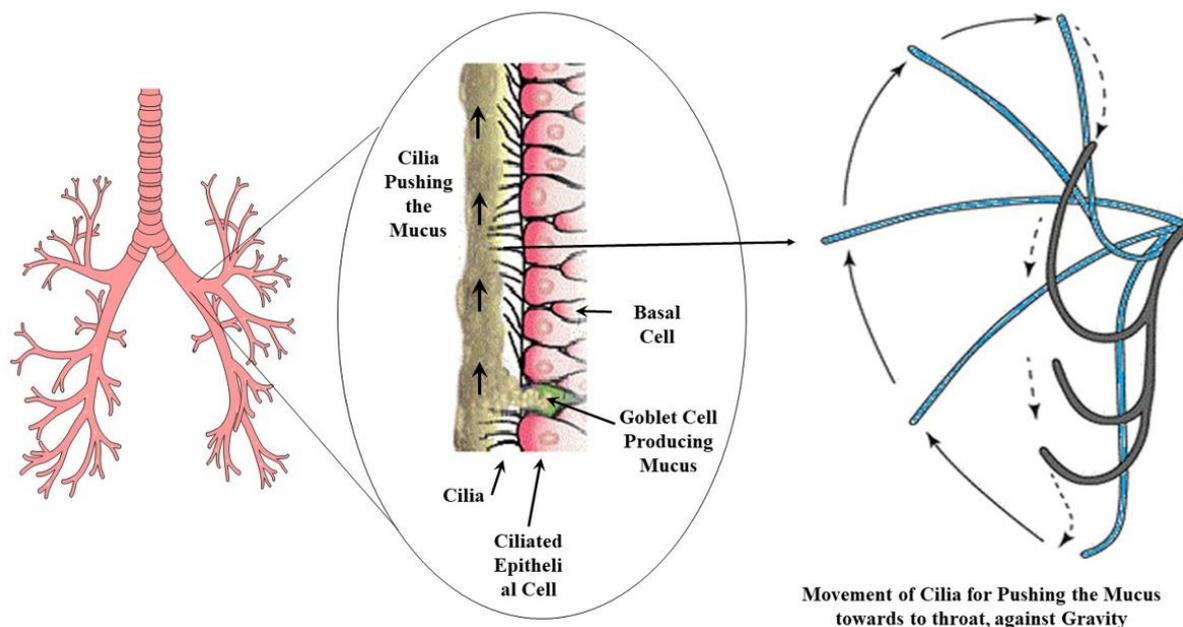
This stage of the disease develops in about 20% of the cases and some cases develop very severe disease also. At this stage, the virus reaches deep into the lungs and infects type II alveolar cells, mainly peripheral and sub-pleural part of the lungs. Then, large number of viral particles are released from the affected cells and as a result, the affected cells undergo apoptosis. The released viral particles further infect nearby type II alveolar cells as well as nearby gas exchange unit. The elderly people are particularly at high risk of developing this stage, because of their immune response is usually weak and have limited ability to recover the damaged respiratory epithelium. The elderly people also have reduced MCC, and this gives the great opportunity to the virus to rapidly spread into the lung<sup>[7]</sup>.

### Mucus, Ciliary Function in Respiratory Epithelium and COVID19

Mucus, various anatomical barriers and various immune cells are excellent defense system in lungs. The primary process which greatly support the immune system in lungs is MCC. Healthy airway surfaces of lungs are lined by ciliated epithelial cells. They are covered with an airway surface layer, which has two components. One is, a mucus layer that is very important to trap inhaled particles including pathogens. Second is, the low viscosity periciliary layer which lubricates the surfaces and facilitates ciliary beating for efficient mucus clearance. Normal ciliary movement is

very essential on regular basis for effective MCC. Cilia are specialized structure which provide the necessary force for the transport of mucus containing trapped foreign particles and viruses from the respiratory tract. The movement happen against the gravity toward to the throat, from where they are either expectorated by coughing or swallowed<sup>[8]</sup>. The cilia of the airways beat in a well-coordinated way, which results in metachronal waves. Each cilium beats at the same frequency in a phase-shifted manner with its neighboring cilium along the axis of the effective stroke. The phase-synchronous beating makes metachronal ciliary stroke (Fig 2), and it moves the mucus layer at a velocity of 2-25 mm/min. Optimal mucociliary clearance is achieved at 37°C and 100% relative humidity

(absolute: 44 mg/dm<sup>3</sup>). This is because, well hydrated condition of the respiratory epithelium keep the mucus layer fluid and help in MCC. Application of sodium-chloride increases ciliary beat frequency (CBF) and thereby improves MCC<sup>[9]</sup>. CBF decreases with increasing age of a person, hence accordingly, MCC may decrease with age. Posture influences MCC by making use of gravitational forces. The effects of gravity and hence the effect on the movement of mucus becomes more important in patients with impaired MCC. Postural drainage by the effect of gravity to enhance MCC are useful in such case. By inclining patients downwards on a bed, the bronchi can be brought into a position for draining out the mucus<sup>[10]</sup>.



**Fig 2. Ciliary Movement in Respiratory Mucosa**

SARS-CoV-2 enter via the nose or the lips, and transmit through the oral cavity, the pharynx and the larynx before entering the bronchi and into the lungs. The virus encounter with the respiratory epithelium with cilia lining at the posterior third of the nasopharynx to the

bronchioles, the first line of defence<sup>[11]</sup>. That's why, if the virus is trapped in mucous at this stage, the normal function of MCC can greatly help in removing the virus before it enter deep into the lungs. The beating frequency of cilia is observed highest in the pediatric population. The COVID19 patients who have been found with breathing difficulties or requiring respiratory support are

majority of old age. This observation may indicate that the epithelial cilia lining of the upper respiratory tract is an important part of the explanation of the age-gradient that is observed in the COVID19 pandemic across the globe<sup>[11]</sup>. If, the mucous is not removed effectively and mucous secretion continue, it leads to mucus plug formation. Additionally, airways, alveoli and endotracheal tube blockages can occur and condition become complicated by emphysema and hypoxia, which are resistant to oxygenation<sup>[12]</sup>. The condition of patient become serious involving mainly respiratory system, because SARS-CoV-2 replicate mainly in the upper and lower airway epithelium and in the lung alveoli. It is reported that, infection of reconstituted airway epithelium showed a preferential targeting of ciliated cells, with an infection of goblet cells in some but not all studies. SARS-CoV-2 have been reported to cause damage to the ciliary layer, with impairing MCC in a reconstituted human bronchial epithelium model, suggesting that cilia loss play an important role in COVID19 pathogenesis. Localized clearance impairment at the site of SARS-CoV-2 replication could facilitate viral spread within the airways. Decreased cilia movement could slow the transport of released virions towards the pharynx and facilitate viral access to deeper regions of the bronchial tree<sup>[13]</sup>.

### **Yoga Practices and Mechanisms of Beneficial Effects**

The upper respiratory tract being the portal of entry for the SARS-CoV-2 infection and COVID19, the health of the respiratory system is very important in preventing further progress of the disease. There are several reports of clinical trials that suggest an overall effect of yoga training toward improved pulmonary

function in patients with pulmonary disease<sup>[14]</sup>. In the context of COVID19, the published articles report that there is an evidence to suggest that yoga practices provide much needed body immunity and could assure a disease-free homeostatic state in COVID19. It is also reported that meditation, yoga asana, and pranayama practices may be effective adjunctive means of treating and preventing SARS-CoV-2 infection<sup>[15]</sup>. Breathing techniques such as diaphragmatic breathing, slow deep breathing and pursed lip breathing are used in strategies to manage patients' breathing patterns and breathlessness, but require expert advice to identify best suited techniques for each patient<sup>[16]</sup>. In view of maintaining social distancing in COVID19, the reported data shows that tele-yoga can be a safe, feasible and useful intervention in improving individual well-being and reducing stress<sup>[17]</sup>.

It is well known that yoga produces beneficial effects on individual at physical as well as emotional level. Yoga greatly enhance physical and respiratory function<sup>[18]</sup>, improve respiratory and cardiovascular function, reduce stress, anxiety, depression, improve sleep patterns<sup>[19]</sup>, improves autonomic functions<sup>[20]</sup>, provides a life-long behavioral skill, and enhances self-confidence<sup>[21]</sup>. Published literature support the utility of integrated yoga as a complementary intervention for populations at risk or already suffering from COVID19<sup>[22]</sup>. One of the published article suggest that the effects of yoga practice based on following 3 basic concepts provides inside into the underlying mechanisms for the use of yoga for stress reduction and immune modulation; and it could be the basis for its complimentary role in the management of an infectious condition like COVID19<sup>[23]</sup>.

- 1) Five aspects of human system and the entire creation in general: Annamaya kosha, Pranamaya kosha, Manomaya kosha, Vignanamaya kosha, Anandamaya kosha<sup>[23]</sup>.
- 2) The incorrect and inaccurate knowledge at the mind level as well as at intellect level can percolate through the brain and HPA axis down to bring distortions in our immune responses<sup>[23]</sup>.
- 3) Yoga techniques to develop mastery over the mind by enhancing the will power that keeps the immune system strong. Along with these practices, a mental attitude known as Pratipaksha Bhavana (contrary attitude) which train the mind to let go of all intense reactions and replace them by positive thoughts of love and acceptance (prashamana)<sup>[23]</sup>.

Based on above 3 concepts, the yoga practice produces deep relaxation which reduces stress to prevent immune-suppression; and help in preventing and curing illness including COVID19. The National Clinical Management Protocol based on Ayurveda and Yoga for management of COVID19 has been released by Government of India, Ministry of Ayush, for the management of asymptomatic and mild cases of COVID19 for prophylactic care. As per this protocol, moderate physical exercises which does not involve powerful physical activities may be practiced<sup>[24]</sup>. Hence, it is recommend to carry-out basic or simple yoga asana in mild COVID19 under the guidance or observation of yoga therapy expert. If person has any symptoms of COVID19 e.g. fever, cough, shortness of breath and breathing difficulties; generally, physical activities including exercise are to be avoided and the person should seek medical diagnosis<sup>[25]</sup>. Because, meditation does not involve any strenuous physical activities, it is one of the

safest practices in COVID19 to relive stress, anxiety and depression. Hypertension, diabetes, sleep disorders, depression, obesity, chronic obstructive pulmonary disease (COPD), bronchial asthma, etc. can be the comorbid conditions in patients with COVID19. The Guidelines for yoga practitioners for COVID19 released by Government of India, Ministry of Ayush suggest that yoga and meditation can reduce susceptibility to acute respiratory infection in patients with such comorbidities<sup>[26]</sup>.

One of the method for improving patient's condition in COVID19 is clearing respiratory secretions. Use of modalities that improve respiratory mucus clearance can prevent complications in patients with COVID19<sup>[27]</sup>. Posture is used as one of the tools to manage COVID19. Physiotherapist assisted positioning for gravity-assisted drainage is recommended for clearing respiratory secretion in COVID19<sup>[28]</sup>. Prone position is used to improve oxygenation by following effects<sup>[29,30]</sup>.

- Improved oxygenation
- Improved respiratory mechanics
- Homogenized pleural pressure gradient, alveolar inflation and ventilation distribution
- Increased lung volume and reduced amount of atelectatic regions
- Facilitated drainage of secretions

Performing yoga asana involve slow and steady movement of body in different positions including sitting, supine, prone, and standing postures. Various yoga asana produce effects on respiratory system comparable to prone position including improvement in drainage of bronchial secretions<sup>[31]</sup>. Similarly, yoga asana involving chest / abdomen / lungs compression (e.g. *Shashankasan*, *Vajrasana Yoga Mudra*,

*Pawanmuktasana* etc.), yoga asana twisting spine in supine position (e.g. *Shava Udankarshanasana*) and backbends yoga asana (e.g. *Salabhasana*, *Dhanurasana* etc.) allow compression and extension of alveoli in horizontal position; which helps in mobilizing the accumulated mucus. Yoga asana like *Sarvangasana*, *Sirsasana* and other inversions / anti-gravity asana allow many of the alveoli units to invert, which are usually vertical in sitting or standing body postures. Hence, with the help of gravity, such yoga asana may help in mobilizing the deeply accumulated mucus also. All these flipping movements of alveoli units help in removing the mucus, which further get transported to throat by MCC; and then get swallowed or coughed out. Similarly, there are many different yoga asana and variations which may benefit the beginners in yoga. Thus, COVID19 patient who are able to ambulate, if practices such yoga asana; it may help in mobilizing the accumulated mucus and may improve the condition.

### **Effect of *Pranayam* Practices on Nitric Oxide (NO) Release and MCC**

NO is one of the important signaling molecules and it has been found to demonstrate antimicrobial activity against several bacteria, protozoa and viruses. NO has been found to inhibit the replication of 2004 SARS-CoV during the early stage of infection<sup>[32]</sup>. NO has been reported to reverse pulmonary hypertension, improve severe hypoxia, shorten the stay in intensive care unit and ventilatory support, and increase the survival rate in 2004 SARS-CoV patients<sup>[33]</sup>. In COVID19 induced acute respiratory distress syndrome (ARDS), inhaled NO has been found to significantly improve arterial oxygenation which provides immediate help and delays respiratory deterioration<sup>[34]</sup>. In addition to this, NO has also

found to involve in upregulation of ciliary motility of airway epithelial cell in response to stimulation<sup>[35]</sup>. Weitzberg and Lundberg has reported that NO increases ciliary motility 15-fold during exhalation with humming (e.g. *Bhramari pranayam*) compared with quiet exhalation<sup>[36]</sup>. Mantra chanting including Om and *Bhramari pranayama* have been reported to improve respiratory functions and preventing airflow obstruction<sup>[37,38,39]</sup>. This is consistency with an idea reported by Taneja MK<sup>[33]</sup> that modified *Bhramari pranayam* (Humming sound) by enhancing the expression of Nitric Oxide and increasing the Carbon dioxide by extended exhalation and alkaline pH may help in preventing coagulopathies and morbidity due to COVID19. Also, the *Anuloma-Viloma pranayam* practice has been reported to cause enhancement in mucociliary beat frequency of the respiratory epithelium<sup>[40]</sup>. All these effects are contributory to MCC, an important mechanism for handling or removal of SARS-CoV-2 virus from the respiratory mucosa.

### **Effect of Mantra Chanting**

Mantras are special phonetic words which bring about extra ethereal vibrations into motion. Mantra chanting activates the static electrical points and cause certain ionic discharges affecting nerve centers of the human brain. Thus, it is well known that sound waves (mantras) plays an important part in effecting the human system as well as plants<sup>[41]</sup>. It is reported that *Yagya* with chanting Gayatri mantra reduces particulate matter and electromagnetic radiations and also increases the antimicrobial activity against human pathogens in the surrounding environment where it is carried-out<sup>[42]</sup>. Mantra meditation has been reported to show significant effect on immune cells manifested in the different

circulating lymphocyte subsets and neuroendocrine axis. Use of a silent mantra has been reported to have association with increased connectivity between posterior cingulate cortex (PCC) and right insula; and help in reducing stress and anxiety along with enhancing immunity<sup>[43]</sup>. All these effects helps in reducing the impact of situation like COVID19 by reducing anxiety, fear, stress and increasing or maintaining the immunity. Thus, mantra chanting has been reported to have beneficial effects in depression, anxiety, stress and cognition<sup>[44]</sup>; and improves mental health and negative affectivity<sup>[45,46]</sup>. In the COVID19 pandemic situation when the individuals experiencing high levels of psychological stress, the positivity followed by modulation of HPA axis through practice of yoga and mantra chanting could help alleviate stress and strengthen the antiviral immune responses<sup>[22]</sup>.

Thus, yoga practices are acting on both, mechanical as well as emotional component of COVID19. Considering feasibility of carrying out various yoga asana, meditation, pranayama and mantra chanting practices, the yoga therapy expert may design best suitable individual or group yoga protocol for patients with COVID19; and yoga therapy may be suggested for prevention as well as treatment or recovery from COVID19.

## CONCLUSION

Science refers to any systematic knowledge-base or prescriptive practice that is capable of resulting in a prediction or predictable outcome. Science is also a continuing effort to discover and increase human knowledge and understanding through disciplined research<sup>[47]</sup>. Yoga is similar type of knowledge, and hence Yoga is now referend as science. One of the

benefits of yoga practices can be their therapeutic effects. There are greater chances that yoga practice which includes yoga asana, pranayam, mantra chanting and meditation under the guidance of yoga therapy expert can support the recovery from COVID19 and hence, it may be integrated into mainstream health care for treatment of COVID19. More clinical research is necessary to evaluate efficacy and safety of various yoga practices. Further research would decide if yoga practice can be recommended as a prophylactic intervention and/or as a therapeutic intervention for COVID19<sup>[48]</sup>.

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### Conflict-Of-Interest Statement

The authors declare that they have no conflicts of interest.

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## REFERENCES

- [1] Lee Y, Jung W, Jang H, Kim S, Chung S, Chae Y. The dynamic relationship between emotional and physical states: an observational study of personal health records. *Neuropsychiatr Dis Treat*, 2017;13:411-19.
- [2] Cascella M, Rajnik M, Cuomo A, Dulebohn SC, Napoli RD. Features, Evaluation, and Treatment of Coronavirus (COVID-19). *Treasure Island (FL): StatPearls Publishing*; 2020. pp-908
- [3] Luo M, Guo L, Yu M, Jiang W, Wang H. The psychological and mental impact of coronavirus disease 2019 (COVID-19) on medical staff and general public - A systematic review and meta-analysis. *Psychiatry Res*, 2020;291:113190.
- [4] Gordon JG, Taylor S. *Coronaphobia*:

- Fear and the 2019-nCoV outbreak. *J Anxiety Disord*, 2020;70:102196.
- [5] Segerstrom SC, Miller GE. Psychological Stress and the Human Immune System: A Meta-Analytic Study of 30 Years of Inquiry. *Psychol Bull*, 2004;130(4):601-30.
- [6] Tan T, Khoo B, Mills EG, Phylactou M, Patel B, Eng PC, Thurston L, Muzi B, Meeran K, Prevost AT, Comninou AN, Abbara A, Dhillon WS. Association between high serum total cortisol concentrations and mortality from COVID-19. *Lancet Diabetes Endocrinol*, 2020;8(8):659-60.
- [7] Mason RJ. Pathogenesis of COVID-19 from a cell biologic perspective. *Eur Respir J*, 2020;2000607.
- [8] Bustamante-Marin XM, Ostrowski LE. Cilia and Mucociliary Clearance. *Cold Spring Harb Perspect Biol*, 2017;9(4)
- [9] Beule AG. Physiology and pathophysiology of respiratory mucosa of the nose and the paranasal sinuses. *GMS Curr Top Otorhinolaryngol Head Neck Surg*, 2010;9:Doc07.
- [10] Houtmeyers E, Gosselink R, Gayan-Ramirez G, Decramer M. Regulation of mucociliary clearance in health and disease. *Eur Respir J*, 1999; 13:1177-88.
- [11] Haheim LL. Epithelial cilia is the first line of defence against Coronavirus; addressing the observed age-gradient in the COVID-19 infection. *Med Hypotheses*, 2020;143:110064.
- [12] Khashkhosha HK, Elhadi M. A hypothesis on the role of the human immune system in covid-19. *Med Hypotheses*, 2020;143:110066.
- [13] Robinot R, Hubert M, Dias de Melo G, Lazarini F, Bruel T, Smith N, Levallois S, Larrous F, Fernandes J, Gellenoncourt S, Rigaud S, Gorgette O, Thouvenot C, Trebeau C, Mallet A, Dumenil G, Gobaa S, Etournay R, Lledo P, Lecuit M, Bourhy H, Duffy D, Michel V, Schwartz O, Chakrabarti LA. SARS-CoV-2 infection damages airway motile cilia and impairs mucociliary clearance. *bioRxiv*, 2020; in press.
- [14] Liu X, Pan L, Hu Q, Dong W, Yan J, Dong L. Effects of yoga training in patients with chronic obstructive pulmonary disease: a systematic review and meta-analysis. *J Thorac Dis*, 2014;6(6):795-802.
- [15] Bushell W, Castle R, Williams MA, Brouwer KC, Tanzi RE, Chopra D, Mills PJ. Meditation and Yoga Practices as Potential Adjunctive Treatment of SARS-CoV-2 Infection and COVID-19: A Brief Overview of Key Subjects. *J Altern Complement Med*, 2020;26(7):547-56.
- [16] Greenhalgh T, Knight M, A'Court C, Buxton M, Husain L. Management of post-acute covid-19 in primary care. *BMJ*, 2020;370:m3026:1-8.
- [17] Jasti N, Bhargav H, George S, Varambally S, Gangadhar BN. Tele-yoga for stress management: Need of the hour during the COVID-19 pandemic and beyond? *Asian J Psychiatr*, 2020;54:102334.
- [18] Yamamoto-Morimoto K, Horibe S, Takao R, Anami K. Positive Effects of Yoga on Physical and Respiratory Functions in Healthy Inactive Middle-Aged People. *Int J Yoga*, 2019;12(1):62-7.
- [19] Woodyard C. Exploring the therapeutic effects of yoga and its ability to increase quality of life. *Int J Yoga*, 2011;4(2):49-54.
- [20] Kothari, A. . (2021). *Yoga And Mental Health: A Review On Efficacy Of Yoga*

- In Managing Stress, Anxiety And Depression: International Research Journal of Ayurveda & Yoga, 4(3), 185-193.
- [21] Bussing A, Michalsen A, Khalsa S, Telles S, Sherman KJ. Effects of Yoga on Mental and Physical Health: A Short Summary of Reviews. *Evid Based Complement Alternat Med*, 2012;165410.
- [22] Nagarathna R, Nagendra HR, Majumdar V. A Perspective on Yoga as a Preventive Strategy for Coronavirus Disease 2019. *Int J Yoga*, 2020;13(2):89-98.
- [23] Nagendra HR. Yoga for COVID-19. *Int J Yoga*, 2020;13(2):87-8.
- [24] Government of India, Ministry of Ayush. National Clinical Management Protocol based on Ayurveda and Yoga for management of COVID-19, <https://www.ayush.gov.in/docs/ayush-Protocol-covid-19.pdf>
- [25] Woods JA, Hutchinson NT, Powers SK, Roberts WO, Gomez-Cabrera MC, Radak Z, Berkes I, Boros A, Boldogh I, Leeuwenburgh C, Coelho-Júnior HJ, Marzetti E, Cheng Y, Liu J, Durstine J, Sun J, Jio L. The COVID-19 pandemic and physical activity. *Sports Med Health Sci*, 2020;2(2):55-64.
- [26] Government of India, Ministry of Ayush. Guidelines for Yoga Practitioners for COVID19, <https://www.ayush.gov.in/docs/yoga-guidelines.pdf>
- [27] Farooqi FI, Morgan RC, Dhawan N, Dinh J, Yatzkan G, Michel G. Airway Hygiene in COVID-19 Pneumonia: Treatment Responses of 3 Critically Ill Cruise Ship Employees. *Am J Case Rep*, 2020;21:e926596-1–e926596-8.
- [28] Thomas P, Baldwin C, Bissett B, Boden I, Gosselink R, Granger CL, Hodgson C, Jones A, Kho M, Moses R, Ntoumenopoulos G, Parry SM, Patman S, Lees L. Physiotherapy management for COVID-19 in the acute hospital setting: clinical practice recommendations. *J Physiother*, 2020;66(2):73–82.
- [29] Pelosi P, Brazzi L, Gattinoni L. Prone position in acute respiratory distress syndrome. *Eur Respir J*, 2002;20(4):1017-28.
- [30] Koulouras V, Papathanakos G, Papathanasiou A, Nakos G. Efficacy of prone position in acute respiratory distress syndrome patients: A pathophysiology-based review. *World J Crit Care Med*, 2016;5(2):121-36.
- [31] Donesky-Cuenco D, Nguyen HQ, Paul S, Carrieri-Kohlman V. Yoga Therapy Decreases Dyspnea-Related Distress and Improves Functional Performance in People with Chronic Obstructive Pulmonary Disease: A Pilot Study. *J Altern Complement Med*, 2009;15(3):225-34.
- [32] Åkerström S, Mousavi-Jazi M, Klingström J, Leijon M, Lundkvist A, Mirazimi A. Nitric Oxide Inhibits the Replication Cycle of Severe Acute Respiratory Syndrome Coronavirus. *J Virol*, 2005;79(3):1966-9.
- [33] Taneja MK. Modified Bhramari Pranayama in Covid 19 Infection. *Indian J Otolaryngol Head Neck Surg*, 2020; 72(3):395-97.
- [34] Lotz C, Muellenbach RM, Meybohm P, Mutlak H, Lepper PM, Rolfes C, Peivandi A, Stumpner J, Kredel M, Kranke P, Torje I, Reyher C. Effects of inhaled nitric oxide in COVID-19-induced ARDS - Is it worthwhile? *Acta Anaesthesiol Scand*, 2020;00:1-4.
- [35] Jain B, Rubinstein I, Robbins RA, Leise KL, Sisson JH. Modulation of airway

- epithelial cell ciliary beat frequency by nitric oxide. *Biochem Biophys Res Commun*, 1993; 26;191(1):83-8.
- [36] Weitzberg E, Lundberg J. Humming greatly increases nasal nitric oxide. *Am J Respir Crit Care Med*, 2002;166(2):144-5.
- [37] Mooventhan A, Khode V. Effect of Bhrumari pranayama and OM chanting on pulmonary function in healthy individuals: A prospective randomized control trial. *Int J Yoga*, 2014;7(2):104-10.
- [38] Abishek K, Bakshi S, Bhavanani A. The efficacy of yogic breathing exercise Bhrumari pranayama in relieving symptoms of chronic rhinosinusitis. *Int J Yoga*, 2019,12(2):120-23.
- [39] Kuppusamy M, Dilara K, Ravishankar P, Julius A. Effect of Bhrumari Pranayama Practice on Pulmonary Function in Healthy Adolescents: A Randomized Control Study. *Anc Sci Life*, 2017;36(4):196-99.
- [40] Bhardwaj A, Sharma M, Gupta M. Endoscopic evaluation of therapeutic effects of "Anuloma-Viloma Pranayama" in Pratishtyaya w.s.r. to mucociliary clearance mechanism and Bernoulli's principle. *Ayu*, 2013;34(4):361-67.
- [41] Karnick CR. Effect of Mantras on Human Beings and Plants. *Anc Sci Life*, 1983;2(3):141-47.
- [42] Pathania M, Bhardwaj P, Pathania N, Rathaur VK, Amisha. A review on exploring evidence-based approach to harnessing the immune system in times of corona virus pandemic: Best of modern and traditional Indian system of medicine. *J Family Med Prim Care*, 2020; 9:3826-37.
- [43] Dagli RJ. Increasing Immunity to Fight against Novel COVID-19: Noninvasive Public Health Approach. *J Int Soc Prev Community Dent*, 2020;10(2):125-6.
- [44] Amin A, Kumar S, Rajagopalan A, Rajan S, Mishra S, Reddy U, Mukkadan J. Beneficial effects of OM chanting on depression, anxiety, stress and cognition in elderly women with hypertension. *Ind J Clin Anat Physiol*, 2016;3(3);253-55.
- [45] Lynch J, Prihodova L, Dunne PJ, Carroll A, Walsh C, McMahan G, White B. Mantra meditation for mental health in the general population: A systematic review. *Eur J Integr Med*, 2018;23,101-08.
- [46] Burke A, Lam CN, Stussman B, Yang H. Prevalence and patterns of use of mantra, mindfulness and spiritual meditation among adults in the United States. *BMC Complement Altern Med*, 2017;17:316.
- [47] Patel J. Science of the science, drug discovery and artificial neural networks. *Curr Drug Discov Technol*, 2013;10(1):2-7.
- [48] Telles S. Positioning yoga in the COVID-19 pandemic. *Yoga Mimamsa*, 2020;52(1):1-4.